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Hydropower development in Nepal

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ABSTRACT

This paper provides an overview of a 100 year history of hydropower in Nepal. The importance of hydropower in Nepal is highlighted and major issues that the country has to consider for the development of hydropower have been analysed in detail. It is the only resource available to generate electricity, both for large export projects and small village mini grid projects in almost any part of the country. The challenges of demand and supply fluctuations, mainly due to the seasonal fluctuation of river discharges, are also described. An analysis of river flow trends shows that the impact of river flow has to be analysed river by river, as the trends are not consistent throughout the country. The social and organisational issues and their relationship with the political stability in the country have also been discussed.

Contents

1. Introduction

Energy is the lifeline for development of a country and is considered to be a key player in the generation of wealth and also a significant component in economic development [50]. Self sufficiency in reliable energy from locally available resources is becoming more and more important economically, socially, environmentally and politically. Due to increased awareness of the urgency to limit one's carbon footprint, the world is inclining towards using and developing sustainable and environmentally friendly resources. Hydropower, wind power and solar power are the three major sustainable energy resources available. Wind and solar power have currently been used for boosting the major grids, as production from these sources depends on weather and are not consistent. However, hydropower is more consistent then the former two and can be used to produce power on a large scale. The main environmental advantage of hydropower is the fact that

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it is renewable and generally produces negligible emissions of greenhouse gases or other noxious emissions [8]. Nepal is fortunate in this context as it has the potential to generate huge amounts of energy from hydropower projects. The climatic and topographic conditions of the country make it favourable to develop hydropower projects.

The annual rainfall in Nepal varies from 250 mm to 5200 mm per annum with an average of 1770 mm/year. The annual runoff from the country is 222 billion m^3/s and annual mean stream flow from snow-fed major river systems alone is 4930 m^3/s [18]. Topographic elevation changes from 60 m at the southern plains to 8848 m at Mount Everest in the north, within a horizontal distance of less than 200 km. The north–south distance is less than 100 km in some instances, which indicates the steepness of its topography and variation in physiographic regions. The physiographic region ranges from tropical forest in the south to the permanent ice-covered arctic in the north.

Steep mountainous terrain and perennial flow in more than 6000 rivers/rivulets makes hydropower widely available throughout the hilly region of Nepal. River systems in the country are divided into three major river basins, namely Koshi, Gandaki and Karnali, two border basins and few small southern basins (Fig. 1). Studies have shown that the hydropower potential is distributed throughout the country. Shrestha [37] showed that the country has the potential of generation of 83,000 MW of installed capacity. Basin-wide distribution of the hydro generation capacity is given in Table 1. Other studies have shown different estimations of total installed capacity of the country, e.g. 200,000 MW [31], and 53,836 MW at 40% dependable flows [13]. There is no surprise that different estimates show different capacities, because the assumption made on different factors, techniques of the estimation and resolution of data used, etc. will affect the final result. Actual hydropower capacities are the summation of all the viable projects in the country whose capacity depends on available technology, tariff rates, market conditions, etc. A project which is not economically viable in a particular condition/assumption may become an attractive alternative in some other condition.

Though these figures are not in agreement, even the smallest estimation shows that hydropower is a source of energy in Nepal that can be planned and developed to fulfill the long term energy needs of the country. Kaldellis [15] suggested that properly designed hydropower plants should lead to considerable profits, contributing also in Greece's independency from imported oil and accomplishing the Kyoto protocol obligations. Like Greece, where hydropower is abundantly available, Nepal is in a similar position and can take advantage of hydropower development. However, despite the abundance of hydropower capacity, Nepal has been unable to harness the resource. This paper aims to provide an overview of the history of hydropower sectors in Nepal and discuss the major issues on hydropower development.

2. History of hydropower development in Nepal

Hydropower has been used for centuries in this country, mainly for grain grinding purposes. Use of the hydropower to generate electricity, however, started in 1911 with the 500 kW Pharping hydropower plant. With the current 665.11 MW of installed hydropower capacity [26], the country has completed a centenary of its first hydro-power plant.

The second hydropower plant was built only on 1934 with 600 kW of installed capacity. These first two plants were built by the then rulers of Nepal to use electricity for their personal use, and the general public had almost no access to the produced electricity. It was only after construction of the 2.4 MW Panauti hydropower project in 1965 that the general public started getting greater access to electricity. The momentum of the hydro-electricity development had started since then (Fig. 2). Fig. 3 shows the list of major hydropower plants built in the country. It is interesting to see that large hydropower plants are built every 10 years (Fig. 3), mainly due to lack of funding and shift of priority from the sector.

Table 1
Basin-wise hydropower potential in Nepal.

River basin	Capacity of small river courses (catchment area 300–1000 km^2)	Capacity of major river courses (catchment area > 1000 km^2)	Gross total (GW)
Sapta Koshi	3.6	18.75	22.35
Sapta Gandaki	2.7	17.95	20.65
Karnali and Mahakali	3.5	32.68	36.18
Southern rivers	1.04	3.07	4.11
Total	10.84	72.45	83.29

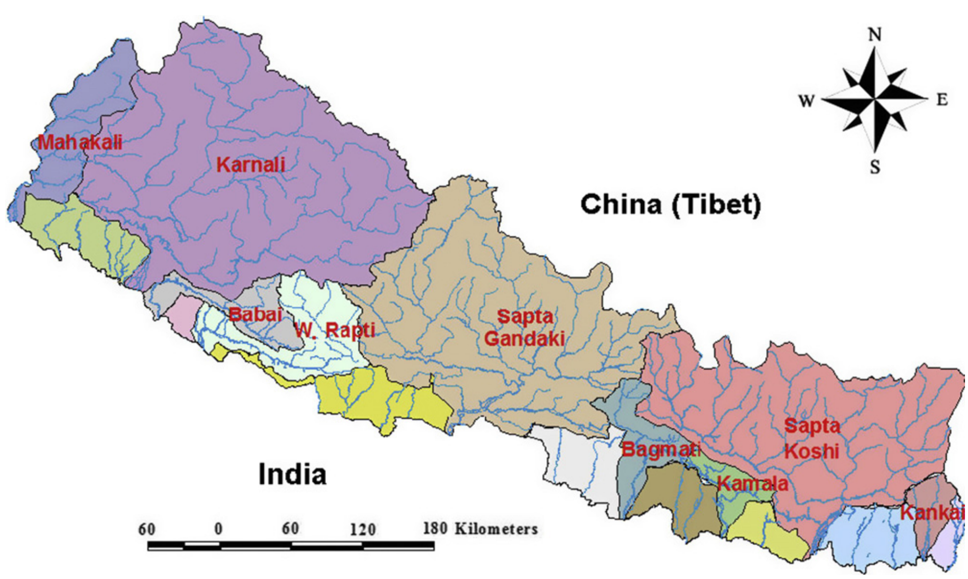

Fig. 1. River Basins of Nepal.

The political system in the country was changed in 1990, which changed the investment policy on the hydropower sector. The hydropower sector was opened for private investment thereafter, which otherwise was owned and developed by the government-linked Nepal Electricity Authority (NEA) only. The intention was to promote participation of the national/international private sectors to invest in the hydropower business. However, in reality, hydropower development was almost halted after the political change of 1990 for almost a decade (Fig. 2). In spite of the new policy, no notable private sectors came forward immediately as the policies were at the initial stages and were unclear.

Also, strong environmentalist movements (e.g. Arun III forcing to withdraw 404 MW), political battles between the parties emerged after 1990; armed conflict by Maoists, etc., fueled the scepticism of national/international investors to invest in the country. Despite the fact, two foreign invested projects, 60 MW Khimti and 36 MW Bhotekoshi, were completed in 2000. The government linked Nepal Electricity Authority built 144 MW Kali Gandaki A and 70 MW Middle Marsyangdi were completed in 2002 and 2008 respectively (Fig. 3).

The pace of development, however, is not sufficient to meet the energy demand in the country because the demand increases with increase in population connecting to the grid, and increase in use of electricity by the population who are already connected to the grid. This increasing deficit between supply and demand starts a period of huge load-shedding. In December, 2008, the Nepal Government declared a "national energy crisis" as it had to cut the power by 16 h a day in the winter of 2008–09. Power shedding reached up to 12 h/day in 2009–10, up to 12 h/day in 2010–11 and reached again up to 14 h/day in 2011–12 [23–25]. Current forecast says the load shedding may reach 21 h a day in the winter of 2012–13 [47].

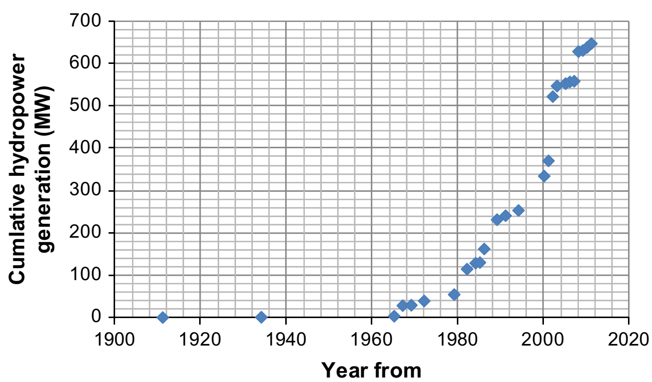

Fig. 2. Trend of hydropower installations in Nepal.

3. Importance of hydropower for Nepal and major issues

Energy sources in Nepal can be divided into two categories (i) traditional biomass related energy sources (fuel wood, agricultural residues, cow dung, etc.) and (ii) commercial energy sources (fossil fuel, hydroelectricity, coal, etc.). Currently, hydropower contributes only 2% of the total energy usage. The bulk of the energy need is satisfied by fuel wood (78%), agricultural waste (4%), animal dung (6%) and imported coal and petroleum products (10%) (WECS, 2010). Excessive dependency on the biomass contributes to deforestation and soil erosion. Researchers have shown that forest degradations are mainly for energy, leading to environmental degradation and subsequently increasing related problems like soil erosion, less productivity, etc. [30].

Similarly, use of imported fuels has serious implications for government finances, society, and the environment at large. For example, in 1999/2000, the total bill for petroleum imports alone was just under 17% of total export earnings (Fig. 4) which has been increasing continuously thereafter. The expense on petroleum products overpasses the total export earnings in 2010/11 (Fig. 4). This year, Nepal imported petroleum products of NRs. 76.7 billion, whereas the total export was valued of NRs. 64.6 billion. Costs of thermal plants are significantly high in Nepal as the fuel products have to be imported. According to the Nepal Electricity Authority, power from the thermal plants is to cost about NRs. 28 per unit [43], whereas the production cost of hydroelectricity was NRs. 9.4 per unit in 2010–11 [25]. No country can sustain such an imbalance for long. Despite the acceptance of the fact that energy is critical for development, energy has not received significant attention in policy debates. The government is directly and indirectly providing subsidies to import fossil fuels and that has favoured the increased use of imported fuels compared to pricy hydroelectricity [14].

Hydropower contributes to meeting both water and energy needs, including water for irrigation and drinking water. It usually works with a wider group of disciplines to maximise hydropower's contribution to sustainable development. Almost half of the cultivable land in the country does not have irrigation facilities. Year-round irrigation facilities are available only for one-third of the land that has irrigation facility. The agriculture products from this limited facility for irrigation and unsatisfactory cropping intensity are hardly sufficient to meet the minimum

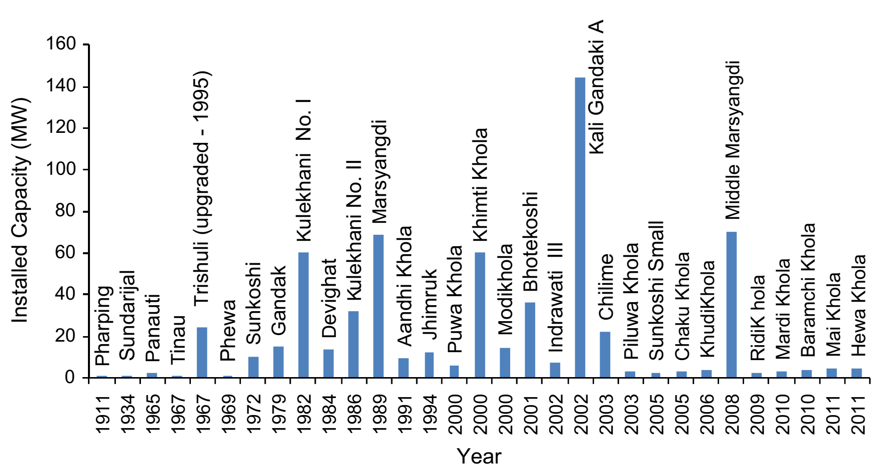

Fig. 3. Timeline of construction of major hydropower projects in Nepal (based on commercial operation date, COD).

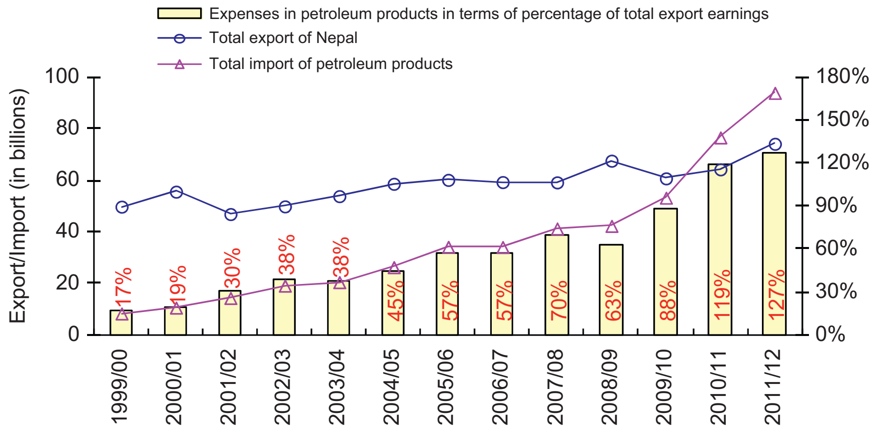

Fig. 4. Expenses in petroleum products in terms of percentage of total export earnings (source: [28]).

Table 2
Power demand projection of Nepal, National Energy Strategy 2010 (GoN, 2010).

Year	2005	2010	2015	2020	2025	2030
Installed capacity (MW)	615	984	1579	2773	5620	11480
Electric power consumption (kWh per capita)	67	80	124	231	496	1070
% of Hydropower in total energy consumption	1	2	4	7	13	17

requirement of the nation (WECS, 2005). If the capital costs are shared between irrigation and power in a multipurpose development, it will not only help address the problem of the irrigation sector but will also maximise the profits from hydropower development [16]. And there will be no issue with the market, because currently only 40% of the population has access to electricity through the grid and off grid system, and demand is increasing.

Estimates of electricity income and price elasticity show that Nepal, for a long period of time, does not have to arrange demand management. It further implies that higher generation will create its own demand. Nepal will need to put more effort into increasing electricity supply investments as a national strategy towards advanced development in the long run [7]. According to the estimations of NEA, energy demand will grow in the next 17 years, with an average annual rate of 8.34%. The National Energy Strategy 2010 projected energy demand on the assumption that the country's economic growth will remain at 5.6% on average till 2030. It has been aimed on the report to meet the growing demand of electricity by building more hydroelectric plants and reduce the dependence on bio mass and fossil fuels, as shown in Table 2.

This shows that there is a huge potential for export of power without compromising domestic demands for the long term. Without entering into the export market, the benefits from hydro generation cannot be maximized, because for the near future the domestic electricity market of Nepal is limited. Nepal's immediate neighbor, India, is a big potential export market for hydropower. India faced an energy deficit of 8.5% and a peak deficit of 9.8% in 2010–11. It is expected that the energy deficit and peak deficit will rise to 10% and 13% respectively in 2011–12 [49]. Regional cooperation in the energy sector in South Asia will extend the electricity market in other South Asian countries. Nepal has already taken policy decisions to accelerate the development of hydropower resources, promote regional energy trade and export surplus hydropower to the countries in the region [2].

Like most of engineering projects, hydropower projects also generally have negative environmental aspects. But if holistically seen, the net impact of hydropower projects on the Nepalese environment may even be positive, because it would reduce CO_2 and SO_2 emissions that would otherwise result from an alternate thermal plant producing the same net output as the hydropower project. The energy usage for cooking and lighting, which is the major energy usage, is currently supplied by firewood. Supplying energy through hydropower is likely to significantly reduce the burning of forest resources.

Table 3
Power production plans for 20 years, the Task Force Report for generating 25,000 MW in 20 years (2010–30) (GoN, 2010).

Year	2010–2014	2015–2019	2020–2024	2025–2029
Power (MW)	2057	12423	5114	18034

Hydropower is important to Nepal because it is the only resource available to generate electricity on a large scale and small local scale both, in any part of the country. Hydropower can satisfy long term energy demands and can also have a good export potential to neighbouring countries. Since this energy resource is renewable and more environmentally friendly than other major resources, the country needs to shift its energy dependency to locally available hydropower.

Understanding the fact, Nepal has given priority to hydropower development for a long time on a policy level. It has formulated various strategies/plans to generate and expand energy services using hydropower from time to time. The Water Resources Strategy 2002, National Water Plan 2005, National Energy Strategy 2010, Hydropower Task force (2010), etc. are the recent examples.

The Hydropower Task Force (2010) plans to build hydropower of 25,000 MW installed capacity within 20 years. The report identified different hydropower projects to be completed and the total power production plans for 2014, 2019, 2024 and 2029 (Table 3).

Despite the interest, hydropower development has not progressed as has been mentioned in the policy, due to a wide variety of issues like technical, environmental, social, and political issues. A brief review of some of the issues has been discussed below. The issues mentioned are not only the listed ones, but they are some of the most prominent issues.

3.1. Electricity demand and river flow pattern

Four months of monsoon season (June–September) with 80% rainfall and eight almost dry months is a characteristic of the Nepalese rainfall pattern. Due to this fact, river discharge also shows large seasonal fluctuations closely following the annual precipitation cycles. Though most of the rivers are snow fed and perennial, snow contribution in the winter is far less than direct rainfall contribution in the monsoon. Fig. 5 shows the specific discharge duration curves of major rivers of Nepal, which shows a very large fluctuation in the river water availability during a year. The figure, however, shows no significant difference between the specific discharge between the snow-fed and non-snow fed rivers. Koshi and Karnali have less seasonal fluctuation than the southern rain-fed rivers. But, despite being large, the snow-fed river Narayani shows higher fluctuation.

Despite the strong seasonal pattern of river flows, almost all the power plants in Nepal are run-off-the-river (RoR) types. This forces the power production fluctuation to follow the river flow fluctuations. The demand, however, is maximum when river flow is minimal, i.e., during winter and vice versa.

At present, the power system in Nepal does not have enough electricity even to meet low demand in the high production period of the year, causing a year round load shedding. Fig. 6 shows the system load curve on the highest demand days of 2005/06 and 2011/12. The comparison of 2006 and 2012 shows that the deficit of generation in 2006 is about 5 h, whereas it is 24 h (whole day) for 2011 on the peak day of the year. It was on 13th January, 2012, when the maximum peak demand reached 1026 MW in the evening [26]. This shows that the peak demand, which is 1026 MW, is more than two times higher than the absolute base demand of around 500 MW.

The figure also indicates that the system is not capable of responding to the peak demand time because the RoR projects are not capable of handling them. Because the total supply is quite less than the demand, only the storage project Kulekhani I has been used to generate electricity throughout the day, which is designed to feed the system during the peak demand. This leads to a huge difference between demand and supply in the evening peak hours.

Fig. 7 also shows that diurnal variations of demand during the winter (December–March), Monsoon (June–September) and pre/post monsoon (April, May, October and November) seasons are not significantly different, though the energy demand in winter is slightly higher than average throughout the day.

Fig. 8 shows the current/average monthly energy production and demand. It can be seen from the figure that the monthly variation of the demand is between 0.9 and 1.1 only. This means that the seasonal fluctuation of energy demand is very low. However, the fluctuation in production is high in all three major hydropower projects in Nepal. The seasonal variation in production varies from 0.6 to 1.3, and has a very similar pattern in all three power plants.

These all show that the patterns in the diurnal and seasonal variations in demand are constant, whereas the supply is largely varying. Large hydropower plants in Nepal are designed with 40–50% dependable flow (Q_{40} to Q_{50}). These plants operate at

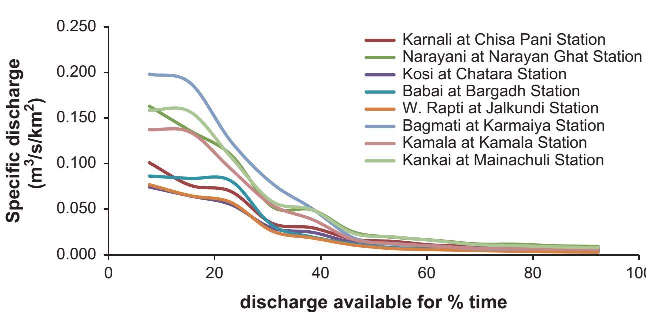

Fig. 5. Specific discharge duration curve derived from monthly flow data of different rivers (Karnali, Narayani and Koshi are snow-fed rivers).

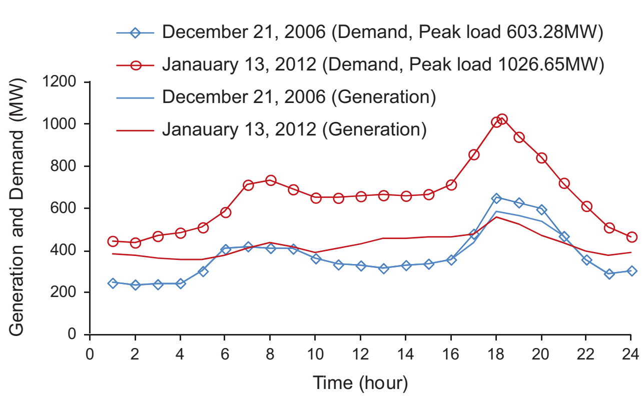

Fig. 6. System load curve of peak days of the years 2006 and 2011.

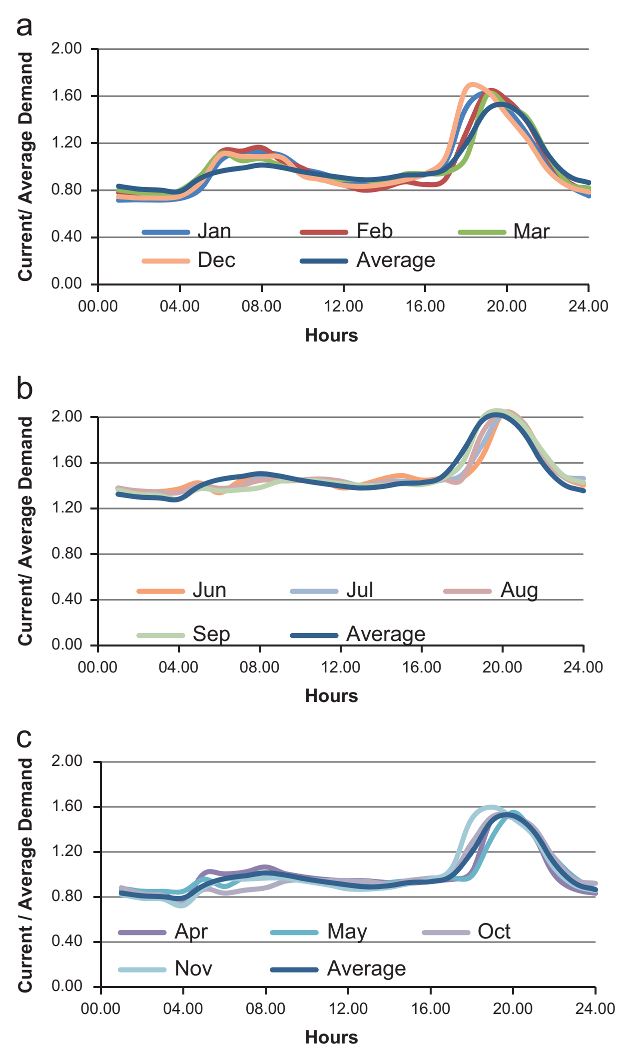

Fig. 7. Seasonal variation in diurnal fluctuation of demand; (a) winter, (b) monsoon and (c) pre and post monsoon.

their full capacity during monsoon and post monsoon months when the demand is low and operate at about 1/3 of their total capacity during the winter season when the demand is very high. The dominance of run-off-river hydropower plants has led to acute energy shortages during the dry season. Once a large project is completed, the wet season sees a glut of energy available in the system [1] After completion of Kali Gandaki A, the Year 2002 saw surplus energy during the monsoon and power shortage during the winter. However, due to current demand and supply conditions, power shortage is there throughout the year, with the winter/dry season being in extreme shortage.

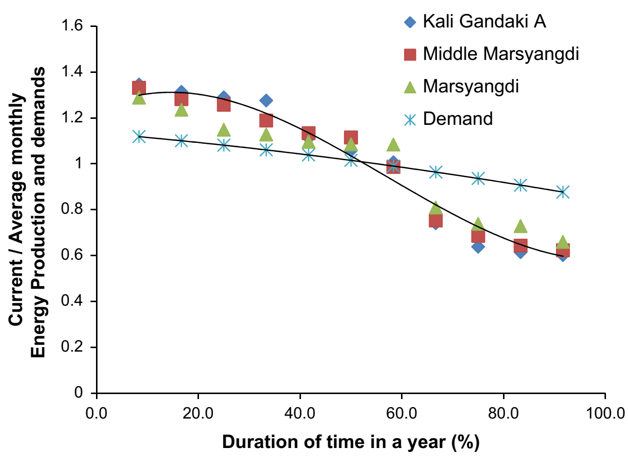

Fig. 8. Current/average monthly energy production and demand.

3.2. Climate change and river flow trends

Fluctuations in river discharge can impact the production of already built projects and potential generation from the "to be" built projects. Hence, climate change and its impact on river hydrology has been a major concern to hydropower development.

Trend analysis of river discharges shows mixed results. The large basins, Karnali, Narayani and Sapta Koshi do not show any significant change (Fig. 9). Kali Gandaki and Trishuli, both tributaries of the Narayani River, and relatively large rivers, show opposite trends in their yearly discharges: Kali Gandaki decreasing and Trishuli increasing. Dudh Koshi, which is a tributary of Sapta Koshi, has no significant trend. Trends in southern rain-fed basins are also not significant. Climate change studies using model predictions also give conflicting reports on future possible changes in river flow. Some studies shows increase in annual run-off ranging from 0 to 150 mm yr^{-1} by the year 2050, relative to average run-off for the period 1961–1990, while the other shows a decrease of up to 250 mm/yr [40]. Analysis of nation-wide river discharges showed that, overall, trends observed in the river discharge are neither consistent nor significant in magnitude [39]. The predicted mean yearly discharge rate is decreasing in the Bagmati river. If we assume a similar trend in its tributaries, it is likely that the power production from the Kulekhani hydropower plant will be reduced by 4% every 10 years [36].

The melt-water contribution of glaciers is particularly important for hydropower projects during dry seasons and temperature trends are important for the fate of glaciers. Temperatures in Nepal are increasing at a rather high rate. Warming seems to be consistent and continuous after the mid-1970s, and the average warming in annual temperature during the period 1977–1994

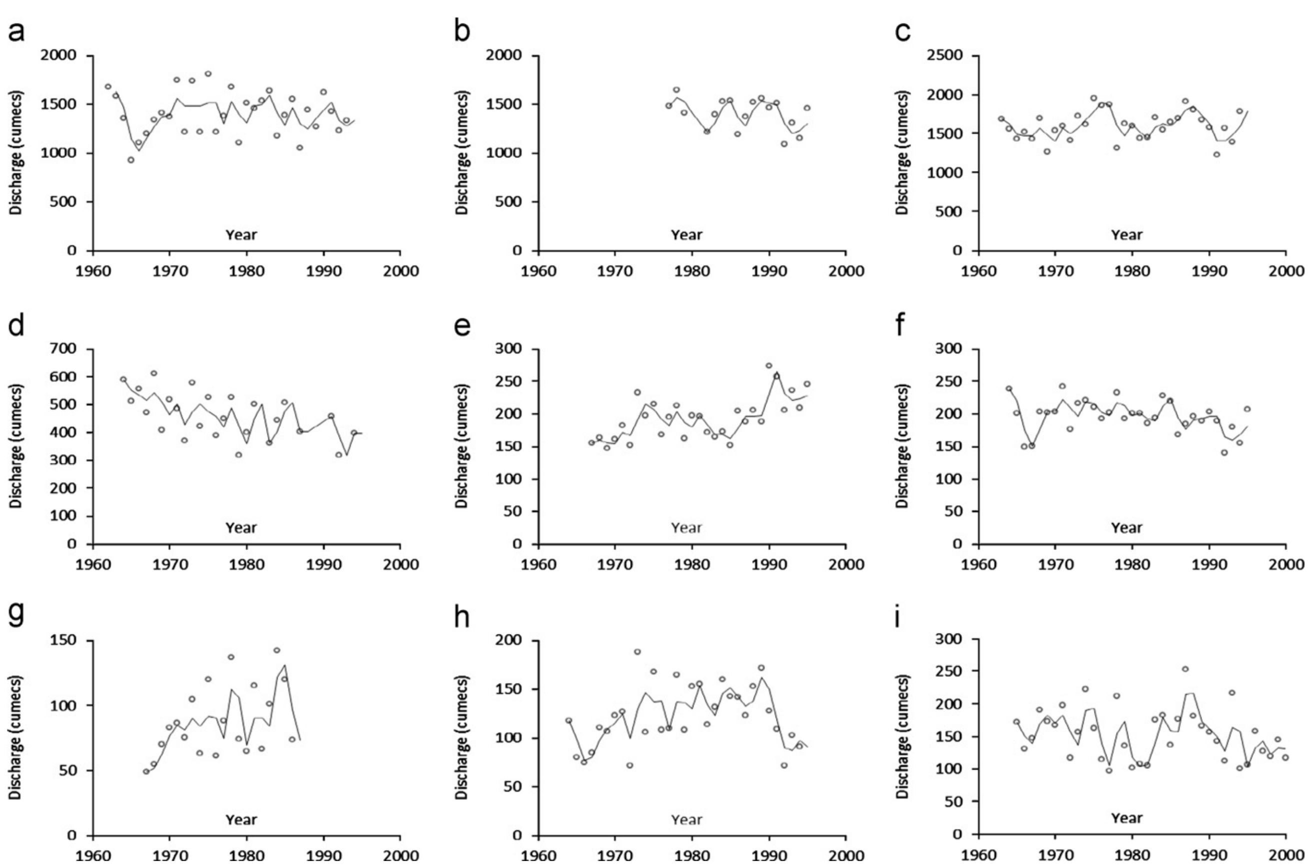

Fig. 9. Yearly discharge and two year moving average trend of some of the rivers of Nepal. (a) Karnali, (b) Sapta Kosi, (c) Narayani, (d) Kali Gandaki, (e) Trishuli, (f) Dudhkoshi, (g) Babal, (h) Rapti River, and (i) Bagmati.

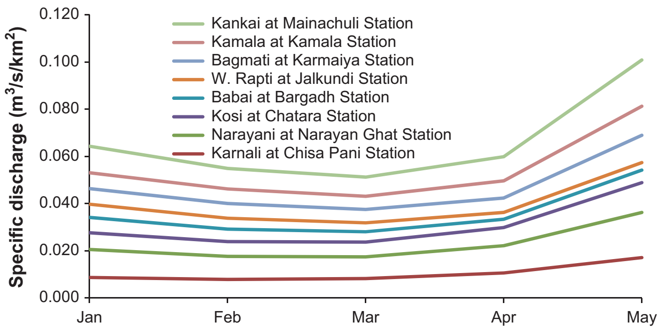

Fig. 10. Flow in the dry winter and pre-monsoon months.

was 0.06 °C/year [38]. This would suggest that those glaciers are retreating. The termini retreat of glaciers in Nepal range from 10 to 74 m in the past few decades [5]. The amount contributed by glaciers is very important to the hydropower projects.

Fig. 10 shows that there is no notable difference between the specific discharge of the southern rain-fed rivers and large snow fed rivers, indicating small influence of the glacier melt in its discharge. Fig. 10 also indicates that the trends of monthly flows in all the rivers in winter (till February) and pre-monsoon months (from March) are similar. If the contribution of the snow was significant in the snow-fed rivers, it could have been expected that the flow graph from those rivers should have steeper rise than the rain-only-fed rivers after March, when the temperature starts to increase. However, there are no notable differences between the trend of discharge in rain-fed southern rivers and snow-fed rivers during the pre monsoon hot months. This simply mean that the contribution of glaciers has little effect on the total discharge, at least on a monthly scale, so the impact of glacier retreat on hydropower projects built on large rivers is not likely to be significant. This may, however, be different for small snow-fed rivers.

3.3. Natural risks to the hydro projects

Glacial lake outburst floods (GLOFs), rainfall and earthquake induced landslides and river turbidity are major natural threats to the viability of hydropower projects in Nepal. GLOFs are important for the safety of hydropower structures because, with increase in temperature, GLOF is likely to be more frequent. The formation and growth of glacier lakes is a phenomenon closely related to the deglaciation in Nepal. Nepal has experienced a number of GLOFs in the past, e.g. the Seti river (∼1550), Bhote Koshi river (1935), Arun river (1968, 1969 and 1970), Dudh Koshi river (1977 and 1985) and Hinku river (1998) are among the biggest GOLFs in Nepal [21]. A small run-off-river hydropower scheme (Namche Smal Hydel Project) was completely destroyed shortly prior to its commissioning due to glacial lake outburst flood (GLOF) of the Dig Tsho glacial lake on 4th August, 1985 [48]. The resulting instantaneous flood discharge at Rabuwa Bazar (90 km downstream of the Dig Tsho glacial lake) is about 2.7 times higher than the mean annual maximum instantaneous flood discharge [4]. There are 2315 glacier lakes of varies sizes, the total area being 75 km^2 [12], out of which about 20 glacier lakes in Nepal are considered to be potentially dangerous to produce GLOFs in the near future.

Due to rugged topography, very high relief and intense precipitation during the monsoon period, the hilly regions of Nepal are very susceptible to landslides. Landslides in the Himalaya are scale dependent, from the massive extent of whole mountain ranges (gravity tectonics) through failure of single peaks to very minor slope failures [11]. Kali Gandaki A and the Khimti Khola hydroelectric projects have had significant landslide issues [9].

As most of the potential hydropower sites lie between Main Boundary Thrust and Main Frontal Thrust, the risk of seismic hazards are also serious. Besides the direct impact of the seismic effect on the dam, there are the possibilities of earthquake induced landslips falling into the reservoir and generating large waves that could breach the dam. Formation of landslide dams along the river and failure of those dams after the accumulation of a large amount of water are further risks in the region. Formation and failure of such landslide dams have been reported in the past [3].

Rivers in Nepal are known to be the carriers of huge sediment load. Erosions and mainly landslides and other mass wasting in the upslope catchment are the major sources of sediment [32]. The sediment load in the rivers during the monsoon season creates a problem for functioning of desilting basins, erodes the turbines and fills up large storage areas of reservoirs. A single 30-hour storm burst in July, 1993, scoured sediments off upstream mountainsides and deposited them in the Kulekhani reservoir, leading to a one-tenth reduction in dam storage capacity [19]. The Khimti hydropower plant (60 MW) has recorded a sediment concentration of up to 8536 ppm [6]. The Kali Gandaki plant (144 MW) had also sediment problems at its desander basin. High concentrations of sediments are causing damage to its turbines long before the average expectations. High maintenance requirements of electro mechanical parts are one of the reasons behind increasing costs of electricity sales. Even with well-designed sediment settling and flushing systems, power plants like Middle-Marsyangdi, Khimti and Jhimruk are having severe erosion problems in turbines [42].

3.4. NEA and its health

NEA has sole responsibility of transmission and distribution of electricity, whereas private producers are also involved in the production. Increased project costs and time delays are happening to all the NEA built projects, which makes the projects very high. Time overruns by such projects were high in many big projects in Nepal. Kulekhani I overruns by 21 months, Marsyangdi overruns by 7 months, Kali Gandaki A overruns by 18 months, Chilime overruns by 60 months and Middle Marsyangdi overruns by 48 months [41]. Similarly, upon completion, the Middle Marsyangdi project cost stood at over NRs. 28 billion, which was estimated to be NRs. 13.65 billion at the beginning of the construction [35]. Similar was the case with the country's largest hydropower plant "Kali Gandaki A". The project was estimated to complete with NRs. 7.35 billion, but took NRs. 12.17 billion to complete [45]. Time and cost overrun risks of such NEA projects are normal. Besides these facts, the NEA funded projects are financially supported by international financial institutions like World Bank and Asian Development Bank which come with certain conditions attached, such as the requirement for international competitive bidding, very strict and long environmental assessment, etc. Same is true with soft loans from the donor countries. These conditions force the project to bring forcing equipment and experts from specified countries, making projects expensive.

Transmission lines and infrastructures are the other major reasons for the high cost of the hydropower projects in Nepal. Good power projects are available at remote sites, which are far from the load centres. To develop projects at those sites, it needs long highways in hilly areas, which itself is quite expensive. Besides those, other infrastructures like water supply and sewage systems need to be built in the area. Finally, it needs long transmission lines to draw the energy to the load centres at central and eastern regions of Nepal. Several Independent Power Producers (IPPs) are unable to

undertake new power development initiatives because of the difficulties in power evacuation [1].

Loss of electricity from the system is another big problem faced by NEA. Losses after generation, during transmission and during distribution from grids are called technical losses. Other losses, like unauthorised usage or thefts, are called non-technical losses. Non-technical losses faced by electric utility companies in the United States were estimated between 0.5% and 3.5% of gross annual revenue, which is relatively low when compared to losses faced by electric utilities in developing countries such as Bangladesh, India, and Pakistan [20]. No official estimate of technical and non-technical estimates has been made so far. But it is widely accepted that NEA's non-technical losses are excessive, and that any initiative to reduce losses must target those losses as first priority [1]. The annual report of NEA shows that the total technical loss was 26.43% in the year 2011–12. The average annual loss in the last 26 years is higher than 25% (Fig. 11). Despite the consistent awareness in documents [22–25], electricity loss from the system is not decreasing at all.

High cost of NEA funded projects, extra cost in transmission and massive leakages put NEA in very bad health. The accumulated loss of NEA in 2011 reached NRs. 27.11 billion, which started in 2003 at NRs. 1.69 billion.

NEA, which is the sole organisation for distribution and selling electricity in the country, was selling electricity at NRs. 6.58 per unit on an average before August 17, 2012, even though the cost of production of electricity per unit (kWh) was about NRs. 9.40 on an average, due to public and political pressures. Recently, NEA raised a tariff of 20% on an average after approval from the Electricity Tariff Fixation Commission [26]. This increase in tariff rate will definitely support the improvement of the financial health of NEA, but the tariff rate is already ahead from the neighbouring states of India; it is NRs. 5.94 in Bihar, NRs. 6.45 in Uttar Pradesh and NRs. 6.08 all over India [33].

With almost 20 staff member per 1 MW of electricity generated and 80 staff members per 1 MW of leakage, the NEA is one of the most poorly managed and overstaffed electric utilities in the world [30]. Over the last ten years Nepal Electricity Authority's (NEA) already poor financial position has been steadily deteriorating. NEA last made a profit from operations in FY 1998, of NRs. 154 million. Although, in FY 2007, NEA made an accounting profit of NRs. 262 million, this resulted from foreign exchange rate gains on the Japanese Yen loan [1]. Foreign invested projects like the 36 MW-Bhotekoshi (US$ 97.5 million) and 60 MW-Khimti (US$134.9 million) are also becoming sources of trouble to NEA, as it has to pay in US dollars, which trends stronger year by year. Just for comparison, the exchange rate (annual average of buying rate) per US dollar was NRs. 70.8 in 2000, and NRs. 85.1 in 2012 [29].

3.5. Political issue

Nepal has been in political instability since the 1990s, which translates to short-term opportunism and corruption by special

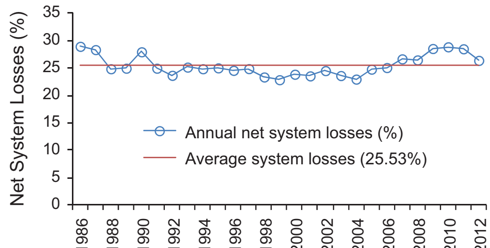

Fig. 11. Annual net system losses in NEA grid.

interests and at the expense of long-term objectives. Complicated and lengthy reforms are not likely to be initiated or to work under political instability [27]. Currently, Nepal is on the phase of drafting a new constitution, changing the Kingdom to a Federal Republic. It is perceived that there is a political uncertainty of ownership of the hydropower projects in the near future federal system of governance.

Hydropower development is directly related to the relationship with India, especially for the export oriented projects. India can be the only country to be a Nepalese partner for the utilisation of water for electricity, irrigation, and flood control and even for navigation. The relationship with India in water resources sharing, however, has not been smooth at any time in the past. The treaty of Peace and Friendship in 1950, the 1954 Koshi River and 1959 Gandak River Agreements are highly controversial in Nepal [34]. Unilateral construction of the Girijapur barrage on the Karnali river, the Tanakpur barrage on the Mahakali river and the Laxmanpur barrage on the Rapti river are also taken as a hostile Indian attitude. The Pancheshwar Project has failed to move for the last 13 years, and the Nepal–India Power Trade Agreement (held in 1996), aimed to medium term (5 yr) import of electricity from India to Nepal and in long term (25 yr) export of electricity to India from Nepal, has also not progressed due to such a complicated relationship.

3.6. Environmental, social and cultural issues

Nepal is a country with very rich aquatic and terrestrial biodiversities. Large hydropower projects, especially large dam projects, can have adverse impacts on many species living in the area. Environmental norms are also not followed properly. It is a general practice that, whatever is written in the document, the hydropower plants during the winter season release no or very little water downstream of the intake, and the river runs dry during the time. This practice has to be strictly monitored and avoided. This is more to do with enforcement of law and following the standards than impact of hydropower itself. Hydropower, in fact, is one of the environmentally friendly energy resources.

Social risks as identified by Messerschmidt [17] are land, shelter, employment, social change, social cohesion, health, nutrition, common resources, education, infrastructure and cultural heritage. In the past, the impact of the projects on the local environment was not taken very seriously, but these days local participation and counselling, trainings, etc. are becoming an essential part of the hydropower projects. The sharing of the revenues among the local communities and investors is becoming the norm these days, but they are also becoming a potential source of tension between the locals and projects in the recent years.There are no clear legal provisions as to how the local community should share the benefit from the project. This is subject of negotiation between the investors and the local communities and there is no arbitrating body in case of disagreements. This leads to conflict between the investors and local communities and in many cases leads to halt of the project sites. Communities close to the power plants want free electricity, besides other demands of water, school, roads, etc. Recently, local communities near the Jhimruk hydropower site padlocked the dam site of the Jhimruk Hydropower Project to press for the fulfilment for their demands of construction of irrigation canals [44]. The Melamchi Water Supply Project has been delayed due to recurrent strikes and local obstructions [46]. Construction projects are often stopped by local communities for reasonable, and sometimes unreasonable, causes [9].

It is important to present project construction and operation in terms of how local communities will benefit. As part of Public

Outreach Programs, the benefits and commitments should be made clear. Avoiding false promises is paramount [9]. Besides providing compensation for the properties of the local people, it is important to make sure that the locals can also share the benefit of hydropower itself built in their area.

4. Conclusion

Nepal has a long history of hydropower plants. Hydropower plants can be built in any part of the country that ranges from micro to large scale; it should be a major source of electricity in the country. Being a local resource, environmentally friendly, and having huge potential, the country should use the resource for its internal consumption and for export. Despite the long understanding that hydropower is a resource to develop for the country's future on a policy level, it has not been implemented well. Hence, the country is crippled with long hours of power cuts through the year.

There are a number of issues that need to be considered while planning hydropower to satisfy the country's energy needs. Developing RoR projects only where the seasonal pattern of flow is very strong will further increase the power cut in winter and will increase power gluts in summer. Hence, a proper mixture of storage and RoR projects should be implemented.

Trends in discharges are not consistent. Though the overall trend is not significant, trends in individual rivers seems to be significantly increasing or decreasing. This factor should be considered and their potential impact on the long run should be accounted for because hydropower projects are expected to run for at least 50 years in most cases.

Because the trend of increasing temperature GLOFs are likely to increase in number, the risks of the GLOF should be considered during design. Their impact can be minimised or avoided if the GLOFs are monitored regularly. Sediment turbidity are bigger issues throughout, and design of desander basins are to be done based on local conditions.

Health of NEA is most important for the development of hydropower projects in Nepal. Maintaining stable political and economic environments can only encourage national/international investments in long term projects like hydropower. Only the political powers will have the will and power to make long term plans without looking for short term political benefits. The relationship with India is another aspect to be thought about seriously. It is important to realise that India is the only country that can be a partner in Nepal's export oriented water resources project. Hence, educating people and creating an environment for open and transparent dialogues with India will help to develop water resources projects of Nepal, which would mutually benefit both countries.

As with any other infrastructure development, hydropower also has advantages and disadvantages; it needs large investment and has social, environmental, political and cultural spectra to be investigated. The focus should be made to minimise the negative impacts.

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